IMPROVEMENT OF COMPOSITE TYPE OF ANTI-ICING PAVEMENT WITH PHYSICAL AND CHEMICAL PROPERTIES

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ABSTRACT

Anti-Icing asphalt pavements used in Japan are roughly classified in physical type and chemical type. In the physical type, there are two construction methods; the one is to uniformly cover the existing pavement with elastic substances, like rubber or urethane, and the other is to pave asphalt mixture containing rubber as an elastic substance. An ice plate on this type of pavement can be removes easily because it is broken by passing vehicles. On the other hand, the chemical type accelerates fusion and removal of an ice plate by sweating of chloride, which makes the freezing point fall down, from the asphalt mixture. We have already developed the composite type of Anti-Icing pavement that has the properties both physical type and chemical type. On the composite type, anti-icing effect is expected in the wider temperature domain than separately on the physical or chemical type. We have constructed this composite type of ant-icing pavement at a few sites, and found a problem of compactability. So, we have modified the mixing ratio of asphalt mixture for the composite type of Anti-Icing pavement to improve its compactability. In this paper, we report results of laboratory tests and a trial field test at Eniwa-city in Hokkaido, Japan on the newly-improved composite type of Anti-Icing pavement.

1. INTRODUCTION

The snowy cold region in Japan, where 20 % of the population lives, accounts for 60 % of the whole land. "The law about prevention of spike tire dust" was enforced in June 1990 and usage of spike tires was perfectly prohibited in April 1992. Afterwards, car accidents and falls of pedestrians in the crossing in the winter increase, so that control of the pavement surface in the winter is important and necessary more and more

Moreover, "Accessible and Usable Transportation Law" aiming at the acceleration of convenience and safety for elders and physically handicapped persons to transfer through public transportation facilities was enforced in November 2000. Thereby, to serve convenience and safety both pedestrians and cars is an important subject, and to achieve the winter barrier-free has been focused on especially in the snowy cold region.

Therefore, in order to prevent the pavement surface from icing, various Anti-Icing pavements have been developed and constructed in the field [1]. The physical type with elastic materials such as rubber chip, and the chemical type with chemicals like chloride are widely known as Anti-Icing pavement.

We have developed the composite type of Anti-Icing pavement, “Twin-Melt Pave“, which has properties both physical type and chemical type. Twin-Melt Pave is expected to show anti-icing effect in the wider temperature range than the physical or chemical type, separately [2] [3], but it has a problem that it is difficult to compact adequately.

This paper reports the results of laboratory tests and trial construction for the new composite type of Anti-Icing pavement that has been improved on anti-icing effect and compactability.

2. BACKGROUND OF STUDY

We have two systems as the provisions against freezing of the pavement surface; one is the facility system to utilize the equipment, and the other is the active system to spray chemicals or support information as shown in Figure-1 [4]. Anti-Icing pavement is a provision of the facility system to control the winter road surface using pavement techniques effectively. Various kinds of Anti-Icing pavement have been developed and can be divided roughly into the chemical type and the physical type by means of their function. The outline, advantages and shortcomings of each type are summarized as following in Japan [4] [5].

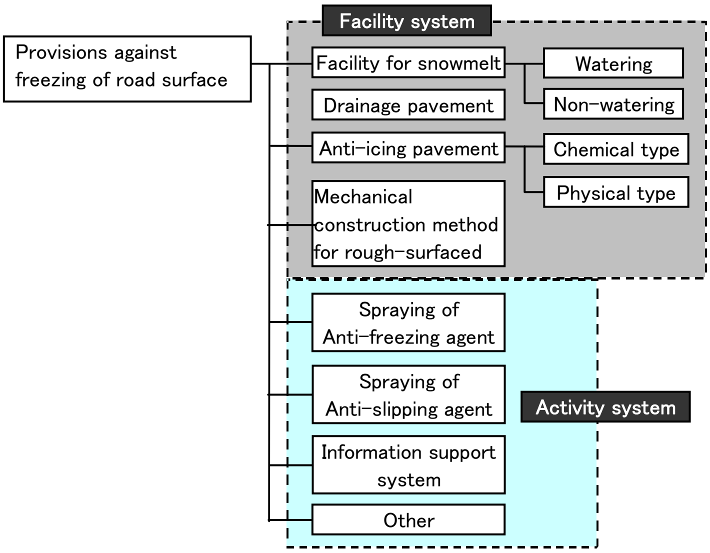

Figure-1 Classification of provisions against freezing of road surface

[Chemical type of Anti-Icing pavement]

<Outline>

This type of Anti-Icing pavement generally has chemicals such as sodium chloride or calcium chloride with the function of freezing-point-depression or melting-ice in the asphalt mixture for surface course. When the chemicals in the asphalt mixture are eluted at the surface due to osmotic pressure or capillary phenomenon, or exposed after abrasion of surface course, the effect to prevent the road surface from freezing and to remove snow or ice from the road surface are expected.

<Advantages>

Even at the road with a low traffic volume, this type has the anti-icing effect due to elution of the chemicals, and it is comparatively cheaper than other provisions against freezing of the road surface.

<Shortcomings>

We have some kinds of chemicals to add into asphalt mixture, however they are useful for anti-icing just when the temperature at road surface is from 0 to minus 5°C. Durability of the asphalt pavement with the chemicals tends to be inferior to that of a general pavement. Moreover, the water after fusion of ice or snow could be frozen again at night. It is also indicated that the chemical type of Anti-Icing pavement does not have the permanent function to prevent the pavement surface from freezing.

[Physical type of Anti-Icing pavement]

<Outline>

One of this type is the pavement of which surface is partly or entirely covered with elastic materials such as rubber or urethane, and the other has the asphalt mixture including an elastic material, for example rubber chip for the surface layer.

Because elastic materials are compressed with traffic loading or the adhesion between snow or ice and the road surface covered with elastic materials is small, this type has the effect to break and remove the plate of snow or ice, and helps the road surface exposed.

<Advantages>

If traffic loading is given, the effectiveness of this type can be demonstrated below minus 5 °C at which the lower limit of effective temperature on anti-icing by the chemical type is.

<Shortcomings>

This type is generally more expensive than the chemical type. Moreover, its effect of anti-icing can not be demonstrated when there is little traffic or the thick layer of snow on the pavement.

As mentioned above, both chemical type and physical type of Anti-Icing pavement have some advantages and shortcomings. The composite type of Anti-Icing pavement that uses rubber chips and chloride simultaneously can be expected to deice the road surface in the wide range of temperature in spite of a traffic volume for a long time, and to overcome shortcomings of the traditional Anti-Icing pavement.

However, since the composite type mixture for Anti-Icing pavement is more difficult to compact adequately than the general asphalt mixture, we have improved the compactability to develop a new composite type of asphalt mixture.

3. LABORATORY TESTS

3-1. Class of Asphalt Mixture

We have conducted laboratory tests on four new composite types of asphalt mixture (Type A - D) and the conventional composite type of asphalt mixture (conventional type) as reference for Anti-Icing pavement, shown in Table-1.

Table-1 Composite types of asphalt mixture for laboratory tests

Article \ Class	Type A	Type B	Type C	Type D	Conventional type
Grade of aggregate	Gap (1)	Gap (2)	Dense (Continuous) (1)	Dense (Continuous) (2)	SMA(13)
Asphalt cement	Polymer-modified asphalt (type ll)				
Asphalt content (%)	6.5	7.0	6.8	6.5	6.7
Percentage of void of mixture (%)	3.0	4.5	3.5	3.5	3.0

3-2. Terms and Methods on Evaluation Tests

The terms, methods and conditions of evaluation tests are listed in Table-2.

Table-2 Terms, methods and conditions of evaluation tests

Term	Method	Condition		
		Non-soaked	Soaked[*1]	Loading in the water [*2]
Strength	Marshall Stability Test	O	X	X
Stripping resistance	Soaked Marshal Stability test	O	X	X
Tension strength	Indirect Tension Test	O	X	O
Rutting resistance	Wheel Tracking Test	O	X	X
Aggregate scattering resistance	Low-temperature Cantabro Test (-20 °C)	O	O	O
Wearing resistance	Ravelling Test	O	O	X

[*1] Marshall-shaped test specimens are soaked for 10 days after compulsive immersion by a vacuum pump. However, the test specimens for ravelling test are only soaked for 10 days without compulsive immersion.

[*2] Cyclic loading is carried out in the water, using a universal testing machine controlled with oil pressure.

3-3. Results of Evaluation Tests

3-3-1. Marshall Stability Test

The result of Marshall Stability Test is shown in Figure-2. From this result, the stability of the new composite types except Type B is improved compared with that of the conventional type.

3-3-2. Soaked Marshall Stability Test

The result of residual stability in Soaked Marshall Stability Test is shown in Figure-3. From this result, residual stability of Type B and Type D is larger than that of the conventional type.

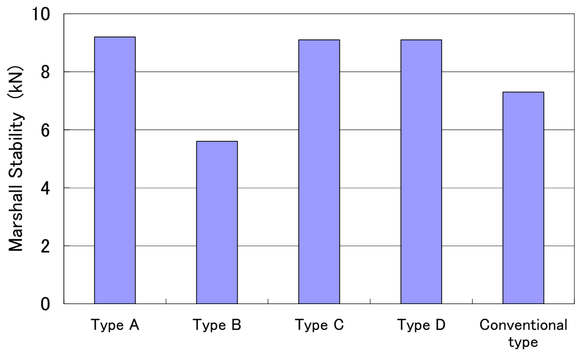

Figure-2 Marshall Stability Test result

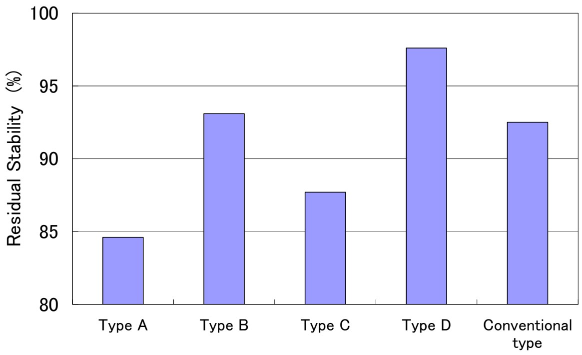

Figure-3 Soaked Marshall Stability Test result

3-3-3. Indirect Tension Test

The result of Indirect Tension Test is shown in Figure-4. From this figure, indirect tension strength of the new composite types except Type B is larger than that of the conventional type. Moreover, the result after cyclic-loading in the water is almost same as that without cyclic-loading.

3-3-4. Wheel Tracking Test

The result of Wheel Tracking Test is shown in Figure-5. From this result, dynamic stability of the new composite types except Type A is improved compared with that of the conventional type.

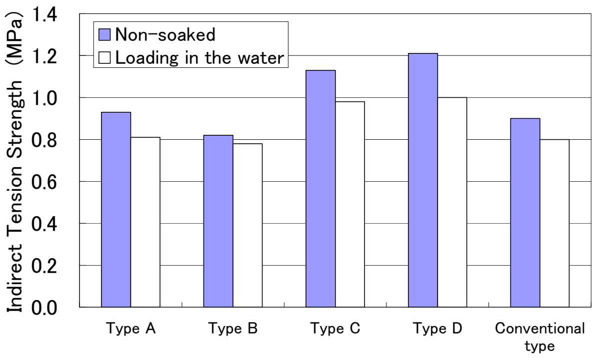

Figure-4 Indirect Tension Test result

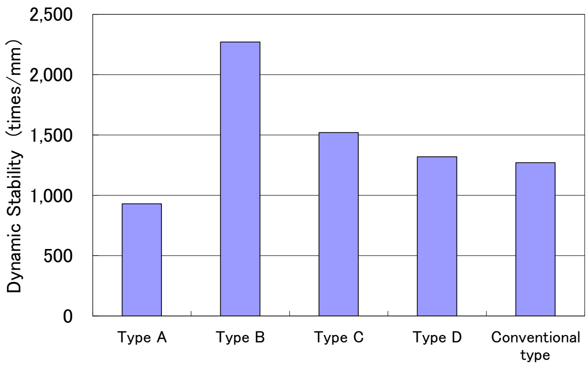

Figure-5 Wheel Tracking Test result

3-3-5. Low-temperature Cantabro Test

The result of Low-temperature Cantabro Test is shown in Figure-6. From this, the new composite types except Type B have excellent resistance against aggregate scattering, because their Cantabro loss ratio is lower than that of the conventional type. Moreover, the result of the specimens soaked or after cyclic-loading in the water is almost same as that without soaked or cyclic-loading.

3-3-6. Ravelling Test

The result of Ravelling Test is shown in Figure-7. From this figure, without soaked, wearing area of Type B and Type C is larger than that of the conventional type; with soaked, Type B's and Type C's is smaller than the conventional type's. On the other hand, without soaked, wearing area of Type A and Type D is almost same as that of the conventional type; with soaked, Type A's and Type D's are smaller than the conventional type's.

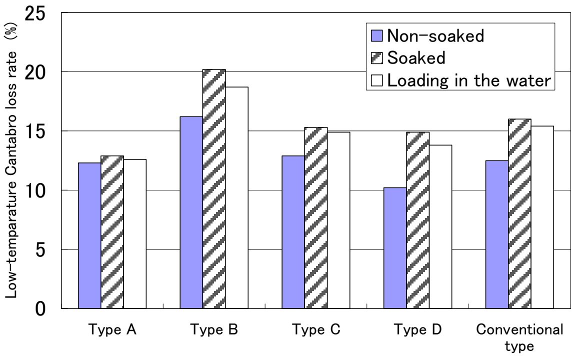

Figure-6 Low-temperature Cantabro Test result

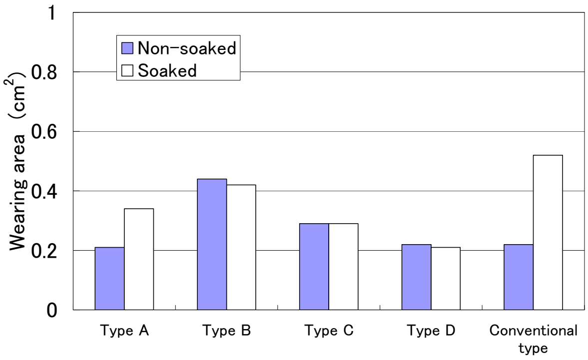

Figure-7 Ravelling Test result

3-4. Evaluation Result of new composite type of asphalt mixture

The evaluation result of four new composite types of asphalt mixture for anti-icing pavement is shown in Table-3, by comparison with the conventional type. The legend of point is following; 3: superior, 2: equivalent, 1: inferior to the conventional type. Because Type D gets the maximum points as shown in Tabele-3, we have determined that Type D has the best property in the total view, compared with the conventional type.

Table-3 Comparison table with conventional type

Valuation method	Evaluation criteria		Type A	Type B	Type C	Type D
Marshall Stability Test	Strength		3	1	3	3
Soaked Marshall Stability Test	Water resistance		1	2	1	3
Indirect Tension Test	Tensile Strength	Non-soaked	2	1	3	3
		Loading in the water	2	2	3	3
Wheel Tracking Test	Rutting resistance		1	3	3	2
Low-temperature Cantabro Test (-20 ° C)	Aggregate scattering resistance	Non-soaked	3	1	2	3
		Soaked	3	1	2	3
		Loading in the water	3	1	2	2
Ravelling test	Wear resistance	Non-soaked	3	1	1	3
		Soaked	3	2	3	3
Total			24	15	23	28

3-5. Confirmation on Mixture Properties (Type D)

Here, we conduct some additional tests to confirm compactability, stripping resistance and the anti-icing effect on Type D determined as the best asphalt mixture in the preceding section.

3-5-1. Compactability

In order to confirm compactability (compaction characteristic), we have compacted the mixture at 10 and 30 times using a Marshall hammer and measured their density to calculate the ratio of density to that at 50 times compaction. The test result is as shown in Table-4.

Table-4 Ratio of density

Terms	At 30 times compaction	At 10 times compaction
Conventional type	99.8%	97.4%
Type D	99.9%	98.8%

This result shows that the compactability of type D is better than the conventional type because at 30 times compaction the ratio of density of both type is almost equal, however at 10 times compaction the ratio of density of Type D is larger than that of the conventional type.

3-5-2. Stripping resistance

We have conducted Soaked Wheel Tracking test to confirm the stripping resistance of the mixture. The test result is shown in Table-5. From this result, the ratio of stripping area on Type D is a little smaller than that of the conventional type and we have never experienced the problem of stripping on the conventional type, so that Type D has the adequate stripping resistance.

3-5-3. Identification of anti-icing effect

In order to check the anti-icing effect of Type D, we have conducted the tensile test to determine adfreezing strength on Type D, and the conventional type and the dense graded asphalt mixture (13) as reference. From Table-6, we can say that the anti-icing effect of Type D compares with that of the conventional type, because the adfreezing tensile strength of Type D is almost equal to that of the conventional type and half that of the dense graded asphalt mixture (13) paved in general.

Table-5 Ratio of stripping area

Terms	Raio of stripping area
Conventional type	4.5 %
Type D	4.0 %

Table-6 Adfreezing tensile strength

Terms		Adfreezing tensile strength
Anti-Icing pavement	Type D	0.27 MPa
	Conventional type	0.30 MPa
General pavement	Dense graded (13)	0.51 MPa

4. TRIAL CONSTRUCTION

On the basis of the laboratory test results, we have tried to construct the Type D of Anti-Icing pavement on-site.

4-1. Trial Construction Outline

Construction Date: September, 2007
Location : Eniwa-city, Hokkaido, JAPAN
Application scope: Length=57 m, Width=2.88 m, Area=164.2 m^2, Thickness=40 mm, overlay after grinding
HMA Haulage : distance=32 km, time=50 minutes
Traffic volume : About 15-40 heavy vehicles / a day / one way
Cross section : shown in Figure-8.

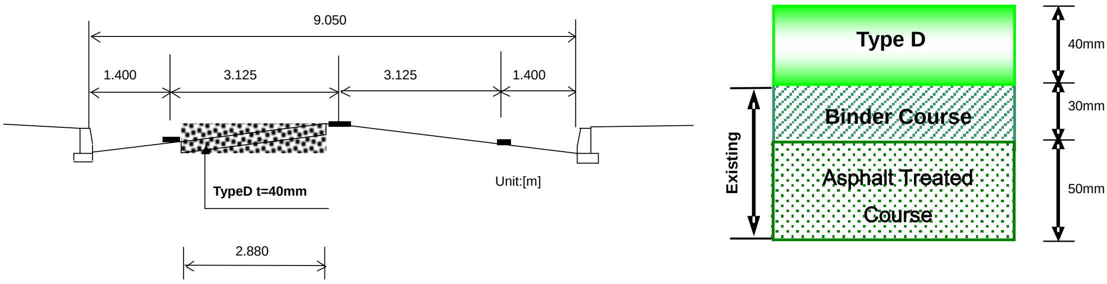

Figure-8 Cross section

4-2. Machines for Trial Construction

The machines utilized for the trial construction are shown in table-7.

Table-7 Machines for trial construction

Name	Specification	Number	Application
Grinding machine	Automatic shipping type	1	Grind of Road surface layer
Dump truck	10 ton (With an exhaust steam heat insulation device)	2	Haulage of HMA & Ground asphalt mixture
Asphalt Finisher	2.4 - 5.5 m	1	Paving of HMA
Vibratory roller	7 ton	1	Compaction of HMA
Tire roller	15 ton	1	Compaction of HMA
Distributor	Spraying system controlled by velocity ratio	1	Spraying of emulsified asphalt (PKR-T containing rubber)

4-3. Conditions for trial construction

Specifications and measurements for the trial construction (temperature of asphalt mixture and rolling times) are shown in Table-8. The temperature to produce asphalt mixture was set as high as possible without harming the asphalt mixture for adequate compaction.

Table-8 Conditions for trial construction

	Terms		Measurements	Specifications
Plant	Temperature	Haulage	183 (1st truck) 184 (2nd truck)	170 ° C or more
On-site		Paving	160-170 ° C	-
		First rolling	155-160 ° C	130 ° C or more
		Second rolling	110-120 ° C	-
	Number of compaction	First rolling	Four round trips	Four or more round trips
		Second rolling	Six or more round trips	Six or more round trips

4-4. Views of trial construction

The views of the trial construction are shown in from photo-1 to photo-6.

Photo-1 Before construction

Photo-2 Road surface grinding

Photo-3 Paving

Photo-4 Rolling

Photo-5 After construction

Photo-6 Close-up of pavement surface

4-5. Test Results on Asphalt Mixture

The test results of asphalt mixture at the trial construction are shown in Table-9, and almost same as those at job mix ratio determined at trial mixing in an asphalt plant before the trial construction.

Table-9 Test result about mixture description

Test item	Mixture of Job mix ratio at trial mixing	Mixture at trial construction	Specifications
Density (g/cm^3)	2.322	2.325	-
Percentage of voids (%)	3.3	3.1	3.5
Marshall stability (kN)	7.4	9.0	4.90 or more
Flow value (1/100 cm)	40	43	-
Residual stability (%)	82.4	82.6	75 or more
Dynamic stability (time/mm)	2,330	-	1,500 or more
Wearing area (cm^2)	0.29	-	0.7 or less

4-6. Follow-up Investigation

4-6-1.Outline of follow-up investigation

To confirm durability, serviceability and anti-icing effect of the composite Type D of Anti-Icing pavement in the trial construction, follow-up investigation was conducted according to the contents as shown in Table-10.

Table-10 Contents of follow-up investigation

Object	Test item		Schedule		
			Immediately after construction	Eight months later	One year later
			Sep. 5, 2007	May. 15, 2008	Sep. 16, 2008
Stripping resistance	Road Surface Observation (Visual observation)		O	O	O
	On-site cutoff core	Modified Lottman Test	O	O	-
		Compressed Water Permeability Test	O	O	-
		Direct Tensile Test	O	O	-
Serviceability	Longitudinal Profile Measurement (Roughness)		O	O	O
	Skid Resistance Test		O	O	O
	Transversal Profile Measurement (Rutting)		O	O	O
	Surface Texture Depth Measurement		O	O	O
Anti-icing effect	Road Surface Observation (Visual observation)		At the surface covered with snow or ice		

4-6-2. Durability and serviceability of Type D

The results of follow-up investigation are shown in Table-11. A ratio of compaction of Type D is 98.7 % immediately after trial construction, so that Type D is able to be compacted without any problems. Moreover, since there is not remarkable change over time in other properties, we can conclude that Type D has good durability and serviceability.

Table-11 Follow-up investigation test result

<table>
<tr><th colspan="3">Test item</th><th colspan="3">Immediately after construction</th><th colspan="3">Eight months later</th><th colspan="3">One year later</th></tr>
<tr><td rowspan="7">On-site cutoff core</td><td rowspan="2">Density measurement</td><td>Density (g/cm^3)</td><td colspan="3">2.294</td><td colspan="3">2.300</td><td colspan="3" rowspan="2">-</td></tr>
<tr><td>Raito of compaction (%)</td><td colspan="3">98.7</td><td colspan="3">98.9</td></tr>
<tr><td rowspan="3">Modified Lottman Test</td><td>Normal indirect tensile strength (kPa)</td><td colspan="3">927</td><td colspan="3">896</td><td colspan="3" rowspan="3">-</td></tr>
<tr><td>Soaked indirect tensile strength (kPa)</td><td colspan="3">772</td><td colspan="3">764</td></tr>
<tr><td>Strength ratio</td><td colspan="3">0.83</td><td colspan="3">0.85</td></tr>
<tr><td>Compressed Water Permeability Test</td><td>Coefficient of permeability [x10^{-5}] (cm/sec)</td><td colspan="3">2.21</td><td colspan="3">1.36</td><td colspan="3">-</td></tr>
<tr><td>Direct Tensile Test</td><td>Tensile strength (MPa)</td><td colspan="3">0.63</td><td colspan="3">0.64</td><td colspan="3">-</td></tr>
<tr><td colspan="2" rowspan="2">Longitudinal profile Measurement (Roughness)</td><td rowspan="2">Standard deviation (mm)</td><td>IWP</td><td>BWP</td><td>OWP</td><td>IWP</td><td>BWP</td><td>OWP</td><td>IWP</td><td>BWP</td><td>OWP</td></tr>
<tr><td>0.97</td><td>-</td><td>1.00</td><td>1.04</td><td>-</td><td>1.06</td><td>1.12</td><td>-</td><td>0.91</td></tr>
<tr><td colspan="2" rowspan="2">Skid resistance test</td><td rowspan="2">BPN</td><td>No.1</td><td>No.2</td><td>No.3</td><td>No.1</td><td>No.2</td><td>No.3</td><td>No.1</td><td>No.2</td><td>No.3</td></tr>
<tr><td>72</td><td>69</td><td>72</td><td>80</td><td>86</td><td>87</td><td>70</td><td>75</td><td>74</td></tr>
<tr><td colspan="2" rowspan="2">Transversal profile Measurement (Rutting)</td><td rowspan="2">Increase of Rut depth (mm)</td><td>No.1</td><td>No.2</td><td>No.3</td><td>No.1</td><td>No.2</td><td>No.3</td><td>No.1</td><td>No.2</td><td>No.3</td></tr>
<tr><td colspan="3">(standard)</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2" rowspan="2">Surface Texture Depth Measurement</td><td rowspan="2">SMTD (mm)</td><td>IWP</td><td>BWP</td><td>OWP</td><td>IWP</td><td>BWP</td><td>OWP</td><td>IWP</td><td>BWP</td><td>OWP</td></tr>
<tr><td>0.26</td><td>-</td><td>0.34</td><td>0.28</td><td>0.25</td><td>0.29</td><td>0.28</td><td>0.29</td><td>0.27</td></tr>
</table>

4-6-3. Surface condition in the winter of Type D

Two examples of pavement surface condition in the winter at the trial construction site are shown in photo-7 and 8. In photo-7, the significant anti-icing effect of Type D surrounded with red lines is not recognized, because the pavement is covered with very thick snow. However, when trying to remove snow from the pavement by hand, we could treat it as blocks on the composite Type D and recognize little snow left on the pavement. On the other hand, it was difficult to tear snow from the reference pavement (Dense-graded 13F) and much snow was left on the pavement surface. Moreover, when we compare the surface condition change over time at Type D with that at the reference pavement in Photo-8, the surface of Type D surrounded with red lines is exposed earlier than that of the reference pavement at the left lane of Type D. From these facts, we can say that the composite Type D of Anti-Icing pavement has the adequate effect.

Photo-7 Road surface condition (Dec. 14, 2007)

Photo-8 Road surface condition (Dec.18, 2007)

5. CONCLUSIONS

We have improved the composite type of Anti-Icing pavement that has both properties of the physical and chemical type in order to progress the compactability. We have applied it to the road at Hokkaido in Japan, and confirmed that the new composite type of pavement has good anti-icing function, compactability and durability through annual investigation on the road surface condition.

In Japan, where the snowy cold district region occupies about 60 % of the whole country, barrier-free in the winter has been one of the important subjects. Road users wish that the high-level safety, comfort to walk and drive throughout a year as well as winter on a basis of enforcement of Accessible and Usable Transportation Law.

We hope to continue carrying out the follow-up investigation and to develop more effective provision against freezing of road surface.

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